I was promised a calm walk in the woods! Achieving Weiser's Vision of Ubicomp by Getting Rid of Ubicomp Technology

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Figure 1: Artist's rendition of Weiser's vision of a walk through the woods.

ABSTRACT

The vision of ubicomp is unachievable with today's approaches. They are fundamentally limited by their use of computing. Instead we propose to use people alone to achieve the vision of ubicomp, of having that refreshing walk in the woods. We describe our use of Weiserians to support this vision by sensing, understanding and acting in the world, and a new metric, the ABOWD, which we use to measure all ubicomp systems by their degree of "ubiquitousness." We further present a mathematical model that leverages Weiserians and this metric to move us much closer to a world where ubicomp truly exists. Finally, we validate our model through a user study, and highlight some limitations that need to be addressed to achieve a zero-ABOWD world.

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Note to the PC Chairs, please schedule the presentation time for our paper to be in the afternoon – as noted in the paper, our smartphone is not reliable way to get us to wake up in the morning.

Author Keywords

Weiserians, ABOWD

INTRODUCTION

It has long been a goal of ubicomp to fulfill Mark Weiser's vision of calm computing in the woods. In his seminal work, "A computer for the 21st century," Weiser ordained that the goal of ubicomp should be to make computers so interweaved within our lives that they become invisible to us [55].

In particular, he wrote:

> "There is more information available at our fingertips during a walk in the woods than in any computer system, yet people find a walk among trees relaxing and computers frustrating. Machines that fit the human environment, instead of forcing humans to enter theirs, will make using a computer as refreshing as taking a walk in the woods."

This vision has fueled research efforts for the past 30 years, opened up avenues of new research, informed the design of many "novel" user experiences [3], has given rise to a large number of companies (Apple's resurgence, Google, Samsung), and provided new tools for government organizations to use (*e.g.*, NSA). Clearly, we have come far in achieving Weiser's vision.

However, the goal of calm computing still eludes us. For years, researchers have deluded themselves into believing that making computers smaller and cheaper somehow makes them calmer. This has created a dangerous, slippery slope. Because computers are now small, it is feasible for them to become embedded everywhere. And because they *can* go anywhere, researchers now feel like they have a contractual obligation to stuff them into every possible object. We now have smart watches that no longer just tell us the time, but instead require us to perform an "intuitive and natural" [37] gesture just so that we can get the screen to turn on 4 times out of 5. There are now smartphones that perpetually notify us that our inbox is full and unmanageable. There are fitness trackers that would remind us that we have still not gone on that 5km (3.1 miles, 2,734 fathoms) run, if we remembered to wear them in the first place. There are even "smart" smoke detectors that can tell us if there is a fire with the same accuracy as their low tech counterparts, but only *after* we install the latest firmware update and download the dedicated app [39].

This paper is meant to serve as a wake up call to the ubicomp community (which we hope will work better than the alarms that never go off on our smartphones because we left them on silent). In today's ubicomp systems, Weiser's dream of a refreshing and serene walk in the woods is anything *but* calm (Figure 2). Instead of fading into the background, we now live in a world where computers are literally strapped to our bodies, constantly vying for our attention, and reminding us that they need to be recharged[1]. And thus, the very devices that researchers have tried to say will help us live healthier and more productive lives have, in effect, become the very things that are preventing us from achieving Weiser's vision.

Ubicomp has become mired in a "proximate future" [5], one that is far messier than we expected. This view, while popular, completely perverts Weiser's vision of truly refreshing (and very non-messy) computing experiences. Others have argued that we should move on from Weiser's vision, focusing on alternatives such as "engaging computing" [46]. A third view is that we should move closer to Weiser's vision to "make using a computer as refreshing as taking a walk in the woods." In 'What next, ubicomp?' [1], Abowd argues that through a combination of Living Laboratories, large-scale deployment of new services, multidisciplinary work, and application-level advances, ubicomp has come a long way. What next, Abowd? The paper argues for simpler development environments, and a 4th generation of computing in which "our sense of identity is no longer easily distinguished from elements of computing" [1, p. 38]

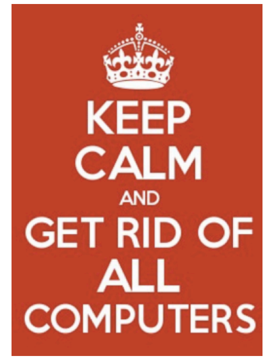

Figure 2. Proposed new advertising campaign for all future Ubicomp conferences.

Abowd further explored a vision of collective computing that is Weiser's ubicomp and emerged in the mid 2000's [2]. He proclaimed that technology allows us to use the "cloud" to merge data from the "shroud" with intelligence from the "crowd" to rapidly empower individuals with specialized expertise beyond their training. We would then be empowering individuals to be their own tour guide, doctor, teacher, you name it. Hey, Abowd, we want to calm down, but not to the point where we have to be wrapped in a burial cloth! And if we have to be our own tour guide, doctor and teacher, we likely will kill ourselves.

How can we leap forward and calm down? In this paper, we emulate the "time machine style research" that Xerox PARC leveraged so effectively to create the first wave of ubiquitous computing. The work we present jumps ahead in time to a new model of ubiquitous computing, where we are no longer hampered by today's technologies, in which we remove computing altogether from our lives. After all, what could possibly be more refreshing than a walk in the woods, than a walk in the woods that doesn't actually involve any computing?

Our vision leverages people, specifically, early adopters who are strongly committed to Weiser's vision. These individuals –we call them *Weiserians*[2]— perform tasks that researchers have tried and failed to design computers to do in a refreshing twist on human computation. Weiserians are disciples[3] of Weiser. They know and love ubicomp. Everything they do is to facilitate the dream of ubicomp. They desperately want to live ubicomp!

Weiserians have many advantages over more traditional ubicomp technology because they trivially can:

- Sense what is happening
- Understand what is happening
- Act on what is happening

[1] By the way, we wanted to remind the reader that your mobile phone is currently low on power and needs to be charged. We'll wait a minute for you to do this.

[2] #notacult

[3] Weiserians also have the added benefit of being willing to turn over their life savings to promote Ubicomp, and work for free to see the vision realized. #reallynotacultweswear.

Years of evolution, combined with years of time wasted on ubicomp technology, have optimized Weiserians to perform these functions in a way that no computer possibly could. As a point of reference, the authors of the paper are Weiserians, and cumulatively have over 80 years of wasted ubicomp effort. Note that our proposed approach is not like the Wizard of Oz technique commonly used by researchers ~~because they don't know how to program~~ to prototype a desired ubicomp system. Nor is it like crowdsourcing where a bunch of random people are hidden behind computers and asked to do what researchers currently cannot do with computers. It is our full intention to embed Weiserians into a new model of ubicomp and let them form a key component of the final working system.

A core benefit of our approach is that it allows us to actually implement the ubicomp systems that researchers have been trying to create for the past 25 years. Instead of waiting for researchers to train the perfect classifier, or to discover the next "magic" interaction technique that will somehow make everything easier to use, our approach gives us a realistic way to create systems that can accurately monitor our activities, notify us of important events, make sure that the oven is turned off when we leave the house and that no one knocks down our house by accident while we are gone [8]. Additionally, our system is dynamic enough that users can quickly reconfigure the system without having to learn some obscure programming language or user interface. Thus, our approach functions like a time machine that provides us a way to actually experience and use these types of systems that we have long talked about in the literature, without having to wait another 20 years for the technology to catch up [30] (#20yearsuntilitsgood).

The contributions of this work are:

- a novel vision for ubiquitous computing that contains a world without computers;
- a model for achieving this unique vision; and
- validation that the model works, thus supporting Weiser's goal of making computational tasks as refreshing as a walk in the woods.

BACKGROUND

Ubicomp systems require three abilities to function—they must sense, understand, and act on what is happening around them. In the following, we will review related work for each of these functions. But first let us introduce an important metric to help assess the state of the art.

The ABOWD: a fundamental unit of ubiquity

We define a new unit of measurement for ubiquitous computing, the ABOWD *(Actually Building On Weiser's Dream)*[4]. The ABOWD is a unit of ubiquity. It measures the degree to which our sense of identity is separate from (or similar to) the elements of a ubiquitous computing system. ABOWD scores range from 0 (truly invisible computing in which the sense of identity of the user and system are one) to 1^*e^{100} (the desktop PC).

Unfortunately, despite the community's best intentions, computers in no way resemble people [57], although they sometimes resemble us at our worst [35], and sometimes even want to destroy us [36]! Thus for most of the history of ubiquitous computing, the ABOWD score of computing systems has been very, very high. Wizard of Oz (WOz) prototyping [15] is an exception to this, which has been applied in ubicomp in a few instances. One of the earliest was Sneakernet, a ubicomp system that leveraged people to deliver information and execute tasks in a shared office space [28]. SUEDE allowed the simulation of speech recognition (and errors) in speech user interfaces [22]. Others have even simulated system robustness during a total power failure [34]. WOz systems have a low ABOWD score, but as can be seen from these references they are hampered by the underlying assumptions of computing systems, such as the expectation of failure. This is because WOz systems are not intended to continue in that vein, but rather to eventually replace people with actual computers, ironically resulting in a significant increase in their ABOWD measure.

Another thread of related work is crowd-powered systems in which computationally intractable tasks are instead completed by people [54]. However, such systems intentionally attempt to hide the crowd behind a computational front-end. Thus, while not as bad as a traditional computational system such as the desktop PC (again, ABOWD score of 1^*e^{100}), crowd-powered systems are by no means a low scorer (a group of Amazon Mechanical Turkers scored these types of systems as having an ABOWD of 1^*e^{99}).

Our vision for ubicomp is to develop systems that have ABOWD scores approaching 0. We now summarize prior work in sensing, understanding, and actuation using these metrics.

Sensing What is Happening

Sensing is core to any context-aware system [9,48], and sensors used in ubicomp-systems range from body-worn sensors (*e.g.*, [6, 32]) to sensors embedded in phones (*e.g.*, [24] to sensors embedded in the environment *(e.g.*, [12]). Sensing systems leverage a range raw data, from location [27] to acceleration to noise [25]. In essence, the ubiquitous computer has a very small but highly personal view of the user's world.

Typically, the goal in sensing is to enable the holy grail of activity recognition *(e.g.*, [16,44]. This in turn can enable applications from in-home activity recognition [10] to workplaces such as hospitals [47] and manufacturing units [51].

[4] Note that many pronounce this as 'abood' or 'aaah-bood' or 'aboud', but true Weiserians know that it is pronounced 'a-bow-d' (underline indicates emphasis).

Sensing research, however, has many shortcomings, some more serious than others. One minor challenge with these sensing systems is that they cannot easily discriminate between overlapping activities, but we have every reason to believe that will be overcome. But even when limited to only a single isolated activity to recognize, no paper we reviewed reported an accuracy of 100%. Even one error in every 100 activity predictions adds up quickly, so these systems are inherently impractical. More importantly, placing sensors anywhere is distracting and annoying and all-too-noticeable, meaning they all get high ABOWD scores. But these shortcomings are minor compared to the incredulous and routine omission of references to the woods or taking a walk (although a few did try to detect walking).

Understanding What is Happening

While activity recognition is often described as a 'holy grail' for ubicomp (presumably such cult-like behavior is primarily driven by Weiserians?), it in reality represents only the first step of ubicomp's walk into the woods. Once activites can be recognized, they may be combined with background knowledge and contextual information to make sense of a situation and/or sequence of action. This brings us to ubicomp's true holy grail: understanding human intention [58] (previously only known to those in the 3rd level of Operating Weiserian and above).

This is a relatively untouched domain in the literature. Some exceptions include Church's work to improve a phone's battery life, reduce app invocation time, and decrease unwanted interruptions [7], Kim's study of driver interruptability [21], Hong's work on aggressive driving detection [18] and Banovic's work on routine detection [4]. In addition to understanding visible situations, there has been research attempts to understand invisible state, e.g., cognitive state and stress level during computer tasks [33] and email usage [31].

More generally, this can be classed as *situational intelligence*. While people differ in their ability to correctly interpret invisible status during everyday social interactions [23], computers are almost entirely incapable of even the most simplest inference on these internal states. Computers can make up for some of this through sheer persistence combined with computation speed (*e.g.,* the recent successful creation of a computer that wins at Go [50]). It is an open question how Weiserians perform on this metric, but one that we will explore.

Acting on What is Happening

Knowledge is limited in impact if you fail to do anything with it. Thus, despite a lack of situational understanding, most ubicomp systems deployed today move straight from activity recognition to action. Perhaps this explains why so many are abandoned [26].

Action may take many forms, from blinking a light [29] to making a sound [38] to actuation. Robotics goes a bit further, but we all know that robots are scary and evil [52].

Figure 3. Just what you think it is: A cat dressed as a shark riding a Roomba.

However, we note that the most successful examples of ubicomp actuation are rarely discussed in the ubicomp. Perhaps this is a tautology; to achieve success, a ubiquitous computing system must be forgotten[5].

For simple examples of acutation, we can consider single purpose actuation that relies on binary triggers. Examples include sliding doors that opens when a person approaches [19], or a coffee pot that begins to brew when the Earth's rotation properly aligns with the sun [55].

More complex decisions typically require better situational awareness, and are only found in the most sophisticated of ubicomp systems. For example, the modern automobile far outstrips most mobile phones in its ability to make a highly complex series of decisions from shifting gears to adjusting levels of fuel injection.

Robots represent a special case with even more complex behavior because of their relative autonomy. However this must be weighed against their relative stupidity. For example, the most commercially successful robot, the Roomba, is a single function actuator on wheels with a clever algorithm for moving around a flat surface. It is primarily of interest to cats attired as sharks (see Figure 3)..

The butler robot, HERB [49], made headlines a little over a year ago for separating an Oreo cookie, a task that even children can accomplish. Another famous robot, Big Dog [43], received accolades for navigating rough terrain and carrying weight. However, despite a $32 million dollar grant, it was never able to accomplish secondary goals such as not being "a loud robot that's going to give [a soldier's] position away" [45].

It therefore comes as no surprise that three primary goals of ubicomp (sensing what is happening, understanding what is happening and acting on what is happening) are all tasks that people are really good at, whereas computers essentially suck at. Thus, we apply people in our new vision of ubicomp. People are a renewable resource: we produce more and more people every day (228,000 daily, as of 2015

[5] The most profound ubicomp research is that which never appeared. #takeTHATweiser

[14]). We just need to convince more of them to become Weiserians (more on this in an upcoming manifesto).

Summary

The challenges of designing ubicomp systems that can successfully sense understand, and act on the human world are immense. We are far from a world where HAL can't let you do that, Dave. Instead, we are in a world where people pre-clean their house before letting "Robby the Robot" (a Roomba) do the one task it was designed for [11]. Modern computer systems are not aware of what's happening. They couldn't understand it if they were aware. AND they can't do anything about what they understand. But at least our fridges can email us [13]. We now present a model that takes us from computing systems with incredibly high ABOWD scores to a system that scores close to a 0 on the ABOWD scale, a heretofore unattainable score.

OUR NEW MODEL

We present a model that reintroduces people back into ubicomp systems[6]. But we're not just interested in any people; only Weiserians need apply for this grand vision! Using Weiserians as the key driver behind our model, we show that systems based on this model are *less* ABOWD than all systems to date.

Putting Weiserians at the core, we immediately solve the first two primary issues for prior ubicomp systems, sensing and understanding what is happening. Weiserians are born with incredible observational skills and unlimited patience, and are true masters of context-awareness [9], which make these two tasks trivial to them. Our model, therefore, focuses on supporting the last function, acting on what is happening. Here, our model was influenced by Horvitz's well-known mixed-initiative framework [17] to gauge the expected utility of a system action to assist a user.

In Horvitz's model, the **e**xpected **u**tility of taking autonomous **A**ction towards a user's desired **G**oal given observed **E**vidence, $eu(A|E)$, "is computed by combining the utilities of the outcomes for the case where the user desires service and does not desire a service, weighted by the **p**robability of each outcome, as follows:

$$eu(A|E)=p(G|E)\ u(A,G) + p(\neg G|E)\ u(A, \neg G)."$$

Figure 4 depicts Horvitz's graphical analysis of the expected utility of an action versus inaction, yielding a threshold **P**robability for action [17]. This model is clearly impoverished since it involves no people in decision making. We will use this as the basis for our model (despite its very high ABOWD score) to help illustrate the differences.

The graphical analysis is very clean and precise, making it easy to see that it is "best for the system to take action if the probability of a goal is greater than p*". As already mentioned, our new model reintroduces people into

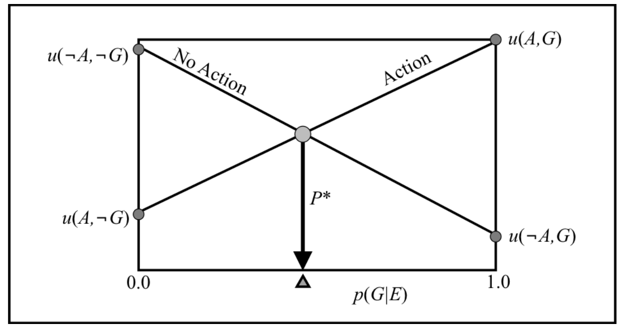

Figure 4. Horvitz' model of decision-theoretic autonomous

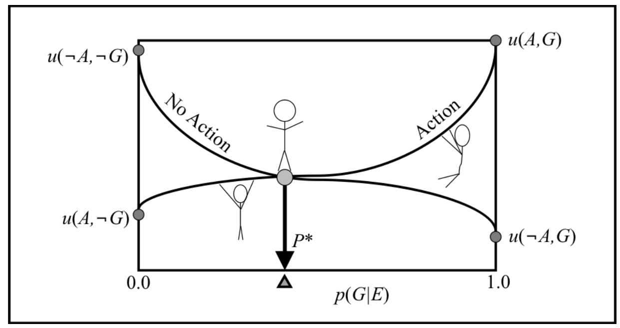

Figure 5. Version 1 of our model.

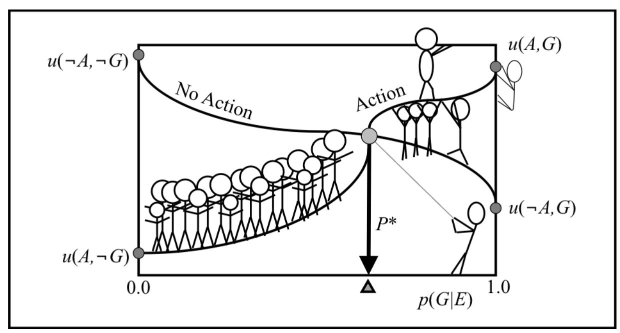

Figure 6. Version 2 of our model that solves for the bendiness of version 1 by replacing *some* people with *many* people.

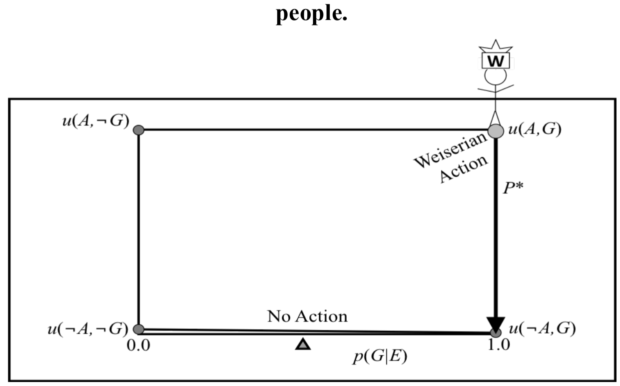

Figure 7. Final version of our model that introduces Weiserian Actions.

ubicomp, and makes them part of the equation. However, as shown in Figure 5, just using *some* people introduces a couple more probabilities that bend the model in various

[6] A so-called human ubicomputation.

directions. To “solve” this, a lot of recent research has attempted to replace using *some* people with using *many* people, *aka* crowds. Again, the mathematical effects of simply making crowds part of the equation are shown in Figure 6. As can be seen, the model becomes quite unpredictable to the extent where it is not even clear that $u(A,G)$ yields maximum utility.

We therefore *extend* the model with **W**eiserian **A**ctions, *WA*. As illustrated in Figure 7 and shown in the next section, Weiserian actions yield infinite utility, hence, $u(WA,G)=\infty$, so that the equation above can be rewritten as: $eu(WA|E)=\infty$. Note that the expected utility of not taking Weiserian actions simply equals Horvitz’s utility, hence $eu(\neg WA|E)=eu(A|E)$.

Per our earlier definition, a ubicomp system that is based on a mixed-initiative approach moves further away from the perfect ABOWD score of 0, the more the initiative is taken by the computer. However, a ubicomp system that is purely based on Weiserian actions yields an ABOWD score close to 0 (theoretically it should be 0, but so far no ubicomp system ever constructed has reached the mythical ABOWD score of 0, or as we refer to it: zero-ABOWD gottanadaABOWD[7]).

PUTTING THE MODEL TO WORK

To assess the effectiveness of our approach and our model, we conducted two studies. Our first study focused on the first two important activities in ubiquitous computing: sensing what is happening and understanding what is happening. Our second study also includes acting on what is happening.

Study 1

To validate our model, our first study observed and recorded the raw activities that a subject performed (sensing what is happening), along with the high-level activities performed (understanding what is happening). The goal was to demonstrate that Weiserians observing a target user are more accurate than any existing technology known to humanity.

Participants

We specifically recruited one subject, a graduate student (32 years of age, male, married with a young son), from an area called “Forest Hills.” Thus, by following him to his residence in Forest Hills, we had already taken a first critical step towards actually achieving Weiser’s dream of refreshing walks in the woods.

We leveraged several aspects of Weiserians to ensure invisibility. First, we capitalized on the marginalization of nerds in general [20]. Second, by employing a number of female Weiserians, we took advantage of the additional way in which women in computer science may be simply overlooked or marginalized [41,53], an extra layer of invisibility available to female Weiserians.

Figure 8. Experimental setup for study #1. Weiserians monitored our subject while remaining invisible and unobtrusive. Please note that the Weiserians’ faces have been obscured for their own protection.

Method

As part of our in-the-wild study, a subset (7) of the authors (all of whom are Weiserians) observed the subject for a period of 24 hours. We asked the subject to behave normally both at home and at the university, with one exception: he was asked to wear a wearable fitness tracker, the Microsoft Band. Each observer played the role of a Weiserian, and observed the subject for 3 hours at a time, with one hour of overlap between consecutive observers. For each activity the subject performed, observers recorded:

- when the subject started and stopped an activity,
- the type of activity (*e.g.*, talking on the phone, going to the bathroom),
- the low-level activity (*e.g.*, sitting, standing),
- the subject’s mood,
- the subject’s location,
- the co-occurrence with other activities (*i.e.*, concurrent with another activity, in parallel with another activity, a solo activity)
- the identity of other people in the environment, and
- the number of steps the subject took during the activity.

Observers also recorded any notes of interest that did not fit into the above categories. We told observers to, as much as possible, behave normally, to be invisible when possible, and not to intrude in the subject’s life where inappropriate (see Figure 8).

In our analysis of the logged data, we examined the accuracy of the results compared to the traditional gold standard of (non-Weiserian) human observation, and compared the observed number of steps to that reported by

[7] gottanadaABOWD

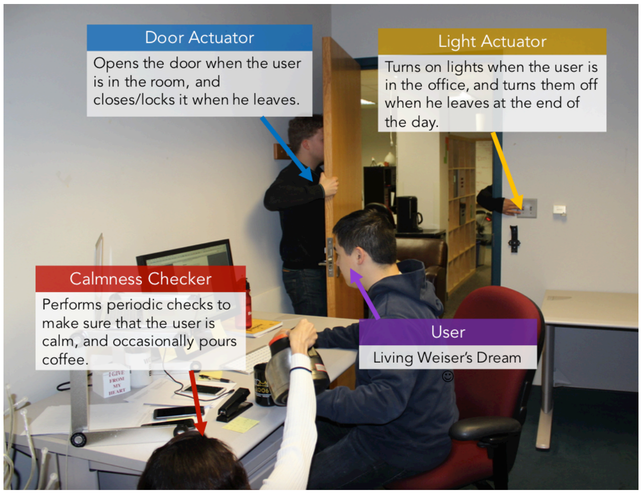

Figure 9. Experimental setup for study #2. Weiserians were strategically placed in a user's office and performed actuation tasks. A calmness checker was also on hand to make sure that the user was calm for the entire study.

Microsoft Band. We also noted down the number and types of activities that Weiserians can observe, but traditional ubicomp technologies cannot.

Study 2

For our second study, we wanted to see how Weiserian-powered systems could be used to achieve perfect actuation. To that end, we hid a number of Weiserians throughout the subject's office to perform common actuation tasks (Figure 9). For example, one was dedicated to opening the subject's door when he entered his office. Another Weiserian was placed near the light switches, and always made sure the lights were on when the subject was in the room.

To ensure that this experience was calm, we also assigned a Weiserian to continually watch the subject and make sure that he was calm. If not, the Weiserian would tell the subject to be calm as quickly as possible.

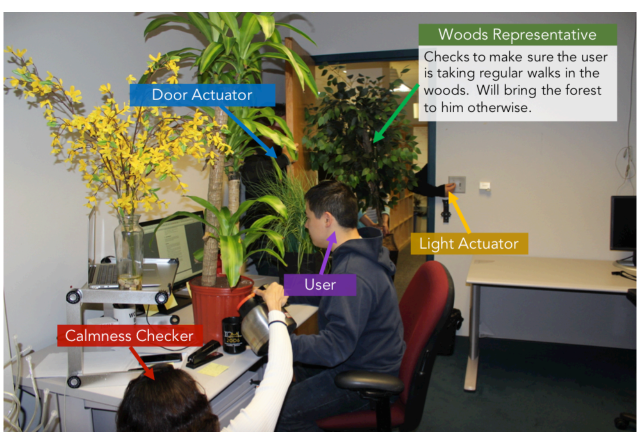

Figure 10. Study #2 after five minutes. If the user does not go to the woods, the system detects this and brings the forest to him.

Figure 11. When the user takes a walk in the woods, our system tells him the calmest path to take.

Finally, we realized that our system was incomplete unless it actually had the user go to the woods. To achieve this, we assigned a Weiserian to make sure that the subject took a walk in the woods. Our system would periodically (once every 5 minutes, so as not to be annoying) remind the user if he was not in the woods. Weiserians would also bring in plants and animals into the subject's cubicle if he didn't go into the woods after multiple (=two) reminders. This way, we could guarantee that the user would experience the woods, one way or the other (Figure 10). When the user finally *did* go to the woods, the system would tell him where to walk, taking into account factors such as the "calmness" of the path (Figure 11).

RESULTS AND DISCUSSION

Here we report the results of our two studies. In our first study, a user was subjected to Weiserian observation with no intervention. In all due modesty, the study was a resounding success in validating our approach for removing all computers to create a new, and the one true vision of ubiquitous computing. There are many factors that lead us to reach this conclusion.

Sensing and Understanding

We noted earlier than Weiserians are just naturally gifted observers and masters of situational understanding. However, to demonstrate this to even the most critical reader, we compared the accuracy of the observations against the ubicomp community's gold standard for labeling data, (non-Weiserian) human observation. Weiserian observation of the subject was 100% accurate! In addition, when comparing the number of steps recorded by Weiserian observers to that recorded by the Microsoft Band, we again found that the former was 100% accurate. The Microsoft Band, on the other hand, exhibited a number of errors in both over counting and undercounting the number of steps compared to what will now become the gold standard, Weiserian observation[8].

We had multiple periods of overlap between Weiserians, to facilitate handoffs, but also to have data collected on the

[8] trademark and patent pending

same activity by multiple observers. In almost all cases, the observers agreed on the activity data. In the few cases where there was disagreement, the human observers discussed the disagreement, came to an agreed-upon observation, thus forming the new gold standard for labeling–making Weiserian recognition accuracy 100% again! In fact, if we consider the number of observations with multiple Weiserians present and the number actions and situations being observed, Weiserians set a new standard with a collective accuracy of 150%!

Some observations from our dataset deserve to be highlighted. Weiserians were superb at detecting both low-level and high-level activities. While we have come to expect our ubicomp technologies to provide us with reasonably accurate information about low-level activities, there is no ubicomp system that can provide accurate information about high-level activities over multiple locations and over a wide range of activities. However, Weiserians can! They could easily distinguish between cooking, talking, paper writing, procrastinating in front of a computer, playing YouTube videos for "research", *etc*., all with perfect accuracy. In addition, Weiserians could sense and understand a range of moods in the subject including: happy, focused, engaged, excited, distracted, amused. This is particularly exciting to us as we know of no other system that can differentiate happy from amused from excited. Our Weiserian-based approach could also determine when a new activity was starting (*e.g.*, cooking) vs. an interruption (*e.g.*, checking on his child when there was a loud noise in another room) vs. multiple independent activities occurring simultaneously (*e.g.*, cooking and talking) vs. a previously interrupted task being resumed (*e.g.*, working on the computer after being asked a question by his son). Again, we know of no other system or approach that can detect this level of activity[9].

Finally, a significant issue with ubicomp technologies is that they are not embedded with human capabilities, knowing when it is appropriate to stop recording, to stop inferring, and to stop remembering. Our approach knows all of these things and more. Weiserians always tried to remain calm themselves and not to interfere with the subject's activities. For example, they intuitively stopped observing when the subject went into the restroom. They kept a polite distance away when the subject put his son to bed and read a good night story. They only used a flashlight to check on the sleeping subject when they were convinced both the subject and his wife were sound asleep[10].

On the other hand, there are limitations to what humans can do as well. Machines are better at *metric* changes. For example, a machine can precisely tell a person's body temperature to a high degree of precision, but another human cannot – trust us, we tried when the subject was sleeping. Humans can generally only detect *ordinal* changes. However, to fully achieve Weiser's vision, we believe that the advantages provided by a human system outweigh the use of traditional machines for sensing activities. It is this limitation though that may forever impede our progress to the mythical ABOWD score of 0.

Acting

In our second study, we focused on the study of our proposed model and the use of Weiserian actions. Based on the results of Study 1 strongly supporting our hypothesis that Weiserians are better than any ubicomp technology at sensing and understanding, we examined how Weiserians perform actions on behalf of the user.

Overall, we found that Weiserians were quite capable of anticipating what our target user needed (even when he did not know himself), and fulfilling those needs. We questioned the user extensively after the study. He reported that his coffee cup was always full ("I've never felt so caffeinated!"), the lighting was always perfect, and the singing (to influence his mood) was a little off-key but still very much appreciated. He was impressed with how invisible Weiserians could be while sensing, understanding and acting. One surprise was the lush forest that formed around him when he thought he could not afford to take a break and go to the woods (Figure 10). He told us: "I just closed my eyes for a moment, and I felt like I was transported to the woods!" Further, when the "forest" was in need of watering, the Weiserians took on this responsibility, sometimes spritzing our user by accident. However, instead of being upset by the breach in invisibility, our user felt quite refreshed—again bringing us another step closer to Weiser's vision of taking a refreshing walk in the woods.

Of course, there were times when the subject did take the Weiserians' advice and go to the woods (Figure 11). He said that he did find this to be very refreshing. Overall, when asked to compare Weiserian Actions to all other forms of ubicomp, he was solidly on Team Weiserian[11].

Not everything was perfect, however. He did mention that he wished he had more Weiserians to help him. At times, the Weiserians were so busy attending to his other needs, that they would not notice that he needed something else and he felt decidedly less calm about that. Given the current limited availability to recruit and indoctrinate Weiserians for some more delicate tasks, we did not have an opportunity to actuate every aspect of the user's life. For example, it would have been nice to be able to instrument the restroom using Weiserians so that the subject would never have to touch the toilet or sink with his bare hands. Indeed, our participated commented, "I bet those Weiserians would know when to turn on the water at the

[9] And we have been REALLY looking!

[10] #Weisertianscare

[11] #nailedit

airport sinks better than that stinking sensing technology!" Furthermore, there are interesting ways to bring the forest into a restroom that we think could lead to interesting design principles. So, we will have to leave this for future work.

DESIGN RECOMMENDATIONS AND FUTURE WORK

Our results have shown that taking technology away from ubicomp has helped us achieve Weiser's vision and take a refreshing walk in the woods. However, there are other visions in different domains that have not been fulfilled yet. We would like to extend our work to other sciences and apply the same concepts[12].

We also postulate that Weiserians can help with other challenging aspects of life as well. Norman's "Design of Everyday Things" [42] highlights design choices that impact the utility of an object. One such example is the "Norman Door"—a door with an ambiguous door handle design, such that a person has trouble distinguishing between a push and pull action. We envision that a Weiserian can be used to help solve such problems[13]. They can help create a world where a chivalrous Weiserian always holds the door open for you, regardless of whether it needs to be pulled or pushed.

The companionship of a Weiserian for day-to-day tasks and activities can have a huge impact on the world. However, currently there is a need to create more Weiserians. For example, a designated Weiserian in each family could accomplish many tasks that currently provoke marital strife and difficulties between parents and children. For example, the concept of '*nagging*' would be obsolete if there were a Weiserian who could help to ensure that nagging was never needed. At this point, we only need as many Weiserians as researchers in the field, as most of our work is used within our community only.

We have thought about how to expand the group of Weiserians in the world. There are a number of researchers in the community that are ripe for indoctrinating into at least the lower levels of Weiserian thought. For example, we can start with the author network graph that connects Weiser to Abowd (see Figure 12 top), and the most published authors in the Ubicomp conference series (see Figure 12 bottom). As of this writing, we have already begun plans to have satellite branches in each of these researchers' hometowns.

As additional future work, we can continue to make Weiserians more invisible. This can occur through the use of technology (*e.g.*, invisibility cloaks [40]), or through better training (e.g., [56]). There were (many) times when the Weiserians were observing the subject at his house, when his child interacted with a Weiserian. While this was not unexpected—as children often observe things that the rest of us do not—it does highlight the need for greater invisibility. Similarly, Weiserians occasionally made themselves be less invisible, for example, by making inappropriate comments like, "That took a while!" after the subject made a trip to the bathroom. We believe that greater calibration of Weiserians will help, by routinely sending them to the woods.

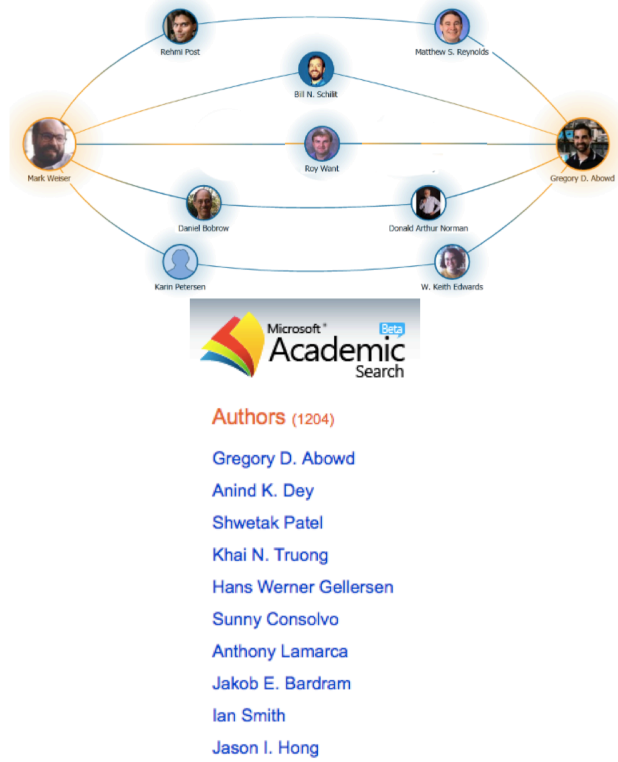

Figure 12. Two sources of future Weiserians: top is an author connectivy graph between Weiser and Abowd; bottom is a list of the top authors in the Ubicomp conference series. Please note that we are unable to indicate which researchers listed are already Weiserians, nor which level they have achieved.

In addition to addressing these limitations, we should also note the very positive impacts of Weiserians in action. The subject being observed said that the observations "made him more productive." Our studies are the first to identify such an effect and future Weiserian studies will need to measure this impact in ABOWD units, which will be very useful and can serve as a benchmark for comparative evaluations of future ubicomp systems.

CONCLUSION

In this paper, we discuss the very real danger of our community failing in its vision to achieve ubicomp, by relying on technology and computers in particular. We propose an alternative, the use of people, specifically Weiserians, to achieve this vision. We describe the many, many, many benefits of using Weiserians, and prove their

[12] #Weiseriansforprotonacceleration

[13] WeiserianstrumpNormians

benefit through a mathematical model and a new metric for measuring ubiquity, the ABOWD. We further demonstrate the benefit of using Weiserians for sensing what is happening in an environment, understanding what is happening and acting on what is happening. Our results unequivocally show that the future of Ubicomp is indeed in good hands, those of Weiserians. In the future, we will continue to strive towards the goal of zero-ABOWD[14].

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[14] #votenoabowd

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